Oak Woodlands

A Southern Sierra Adaptation Workshop Information Brief

DISTRIBUTION

Several canopy species occur as oak woodlands and forests or as components of pine/fir dominated forests. These include (from lowest to highest elevation): blue oak, valley oak, canyon live oak, and California black oak. Other species are present in smaller amounts. Since oaks are often subdominant species, their full distribution is usually not accurately mapped. Areas dominated by oaks comprise about 7,000 km^2 (4,400 mi^2) while areas that include oaks as a subdominant species comprise about 5,000 km^2 (3,100 mi^2) in the study area (Figure 1); together, about 21% of the total area. Oak woodlands support the highest animal biodiversity out of all habitats in California, with over 330 species of birds, mammals, reptiles, and amphibians[1,2,3].

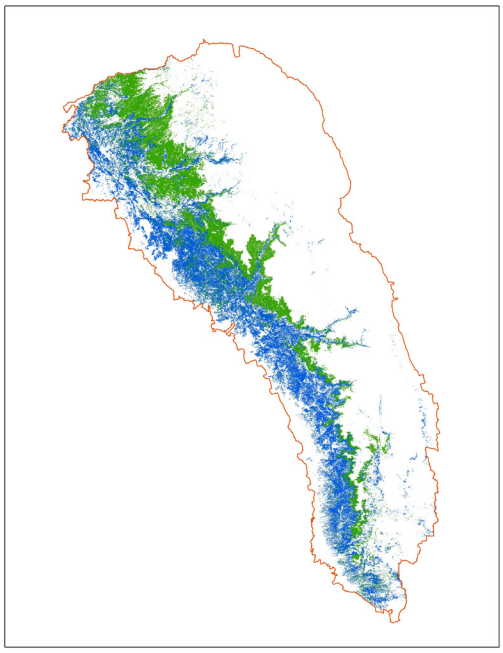

Figure 1: Distribution of oaks in the southern Sierra Nevada park area centered ecosystem (PACE) (CalVeg: blue = oak dominant; green = oak subdominant)

CURRENT CONDITIONS AND STRESSORS

Perhaps the most significant historic and present disturbance or stressor has been the conversion to agriculture and urbanization which have significantly reduced the extent of oak woodlands in the state[4,5]. Thorne et al. examined vegetation changes between 1936 and 1996 in the northern Sierra Nevada and found that the distribution of low elevation oak woodlands and forests (particularly blue oak and valley oak) shrank 50% while upper elevation hardwoods (primarily California black oak and canyon live oak) increased almost 300%[6]. Changes in extents were likely driven by land use changes, successional forces, and climate change. Urbanization (and associated habitat conversion) is sometimes cited as the biggest driver of oak woodland loss in the state[7]. Most of the distribution of oaks in California and the Sierra Nevada is on private lands[4,8,9,10,11]. For example, only 11% of the blue oak state distribution is under public agency ownership[12] though higher elevation species such as black oak have a larger percentage within public lands.

Throughout much of the current distribution of oaks, the suppression of new tree recruitment may be the largest issue facing oak woodlands today, with many possible factors hypothesized including overbrowsing, altered fire regimes, competition with non-native grasses, changing climate, and others[13] (Table 1). At least some evidence points to overbrowsing and predation by cattle, deer, and rodents as significant factors in reducing seedling recruitment[14,15.] Much of the distribution of blue oak, valley oak, and even California black oak in the Sierra Nevada foothills are rangelands with intensive cattle grazing. This, combined with the potential displacement of deer predators[16] and consequent higher predation of

seedlings and acorns appear to be significant stressors for oaks. Examinations of oak woodlands have found that populations lack the younger tree classes with most trees 75 years or older[16,17,18,19], and although acorn production and germination appear to be occurring, sapling survival is low[17,19]. Within Sequoia and Kings Canyon National Parks (SEKI), there is some regeneration, although probably not enough to compensate for the death of adult oaks[20,21,22,23]. In Yosemite National Park (YOSE), the younger size classes of black oak are almost entirely absent[16,18].

Before Euroamerican arrival, historic fire return intervals (FRI) in oak woodland ecosystems were generally 8-14 years[24]. Now, over 75% of oak woodlands have not been burned since 1910, and 94% of this area has a fire return interval that is 3-4 times longer than historic[25]. The role that fire plays in oak recruitment and survival has been investigated, and generally, lack of fire has not been implicated in the suppression of recruitment, but fire can kill oaks, especially the smaller size classes. Fire is important for oak regeneration (regrowth of killed stems), but not necessarily for recruitment (addition of new individuals)[24]. Furthermore, Native American burn regimes are reported to have increased acorn production[26,27].

Beyond recruitment problems, adult oaks can experience heightened mortality near human developments, primarily through erosion, soil compaction, and altered hydrology[28]. Invasive species are prevalent in the understory, which exacerbates other issues for oak woodlands (see Table 1).

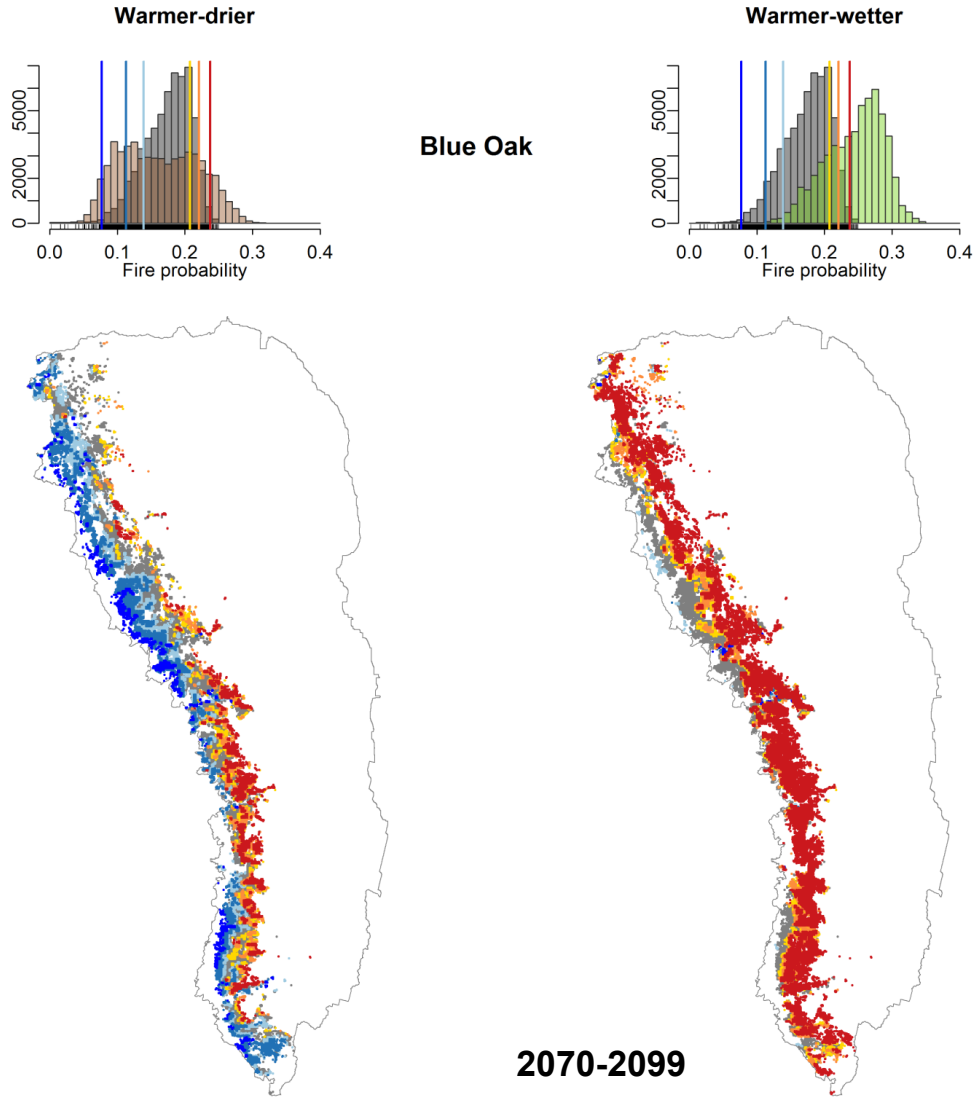

Figure 2: Two scenarios of future (2070-2099) fire probabilities for areas currently dominated by blue oaks in the S. Sierra. Map colors represent where future fire probabilities fall within the baseline (1971-2000) fire probability distribution as shown in the charts above.

Red > 99th percentile
Or = 90-99th percentile
Yel = 64-90th percentile
Grey = 34-63rd percentile
Lt. Bl = 10-33rd percentile
Med Bl = 1-9th percentile
Dk Bl > 1st percentile

The current distribution is shown in grey in the charts with future distribution in brown (left) or green (right). Figure from Max Moritz, UC Berkeley.

Table 1: Current stressors, potential climate change impacts, and characteristics affecting oak woodland adaptive capacity
Stressors are loosely ranked in terms of impact to oak woodlands – VH=very high, H=high, M=medium, L=low, P = potential.

Stressor	Mechanism	Effect on Oak Woodlands
Increased Human Development (VH)[4,5,7]	Habitat loss (H)	Mortality, fragmentation
	Energy and transmission line development (H)	Erosion and alteration of soil nutrients; introduction of invasive plants; fragmentation
	Roads (M)	
	Conversion of native habitat to intensive agriculture (L)	Mortality, fragmentation; exposure to pesticides and herbicides
Predation & Overbrowsing by stock and deer (VH)	Predation of leaves, acorns, seedlings, and saplings	Mortality of oak seedlings; low recruitment
	Preference for native grasses	Increase in invasive plants; changes in native plant diversity
	Soil compaction from hooves – decrease permeability	Decreased recruitment success
Predator Control/ Trophic Dynamics (H)	Hunting of predators led to increased herbivore (deer, rodents) populations	Increased oak seedling mortality
	Displacement of mammal predators[16]	Increased oak seedling mortality
Invasive Plants (M)	Extremely dense groundcover of invasive grasses	Competition with oak seedlings for resources
	Altered fire regime due to dense groundcover	Possible increased adult and sapling mortality
Air Pollution (M)	Increased ozone levels and nitrogen deposition[20]	Foliar injury; lower recruitment success; increase in invasive plants
Fire Suppression (P)	Understory contains dense growth of exotics	Decreased recruitment; change in fire regime
	Lack of stimulation for fast vertical growth of oak sprouts	Oak saplings remain within reach of browsing herbivores
	Lack of nutrient release in soil	Soil not as favorable for oak germination
Pathogens/Pests (P)	Sudden oak death (Phytophthora ramorum)	Potential Increased adult oak mortality (for black oak, canyon live oak, tanoak)
	Gold spotted oak borer (GSOB); canyon live oak and black oak are hosts	Mortality - loss of trees and woodlands
Other (M)	Timber management; intentional prevention of threatened and endangered spp occurrences; non-native animal introduction[25]	Altered species composition and dominance; decreased recruitment; changes in soil chemistry[25]
Potential Climate Impacts	**Potential Results**	**Potential Impact to Oak Woodlands**
"Much Warmer/Much Drier" Scenario	Earlier snowmelt[29,30,31]; decrease in snow pack[29,32]; changes in hydrology; increased soil evaporation rate in summer	Increased oak seedling mortality/decreased recruitment
	Drought conditions during growing season	
	Warmer temperatures during wet season	Increased populations of invasive plants
	Earlier and longer fire seasons; more severe fires and larger areas of high fire intensity, increased fire probability at all elevations except lowest foothills[36]	Increased mortality of adults and seedlings; stimulation of regeneration
	Change in invasive plant populations	Decreased recruitment; change in fire regime
	Shift in plant species composition	Unknown impacts
	Shift in range to track required climate conditions	Oaks may move higher in elevation, but dispersal, browsing, and soil conditions are factors
	Reduced recruitment & shift in population structure	Eventual thinning and loss of woodlands
"Moderately Warmer/ Similar Precip" Scenario	Increased fire probability at almost all elevations[36]	Increased mortality of adults and seedlings; stimulation of regeneration
Sensitivies and Vulnerabilities	**Explanation**	**Potential Impact to Oak Woodlands**
Limits on Reproduction	Current low recruitment with many suspected drivers, including overbrowsing, fire suppression, invasive plant densities, grazing, etc.	Continued decline of oak populations; may not be able to shift range in response to climate change
Synergistic Effects	Already weakened oaks may become more vulnerable to new stressors and new combinations of stressors brought on by climate change	

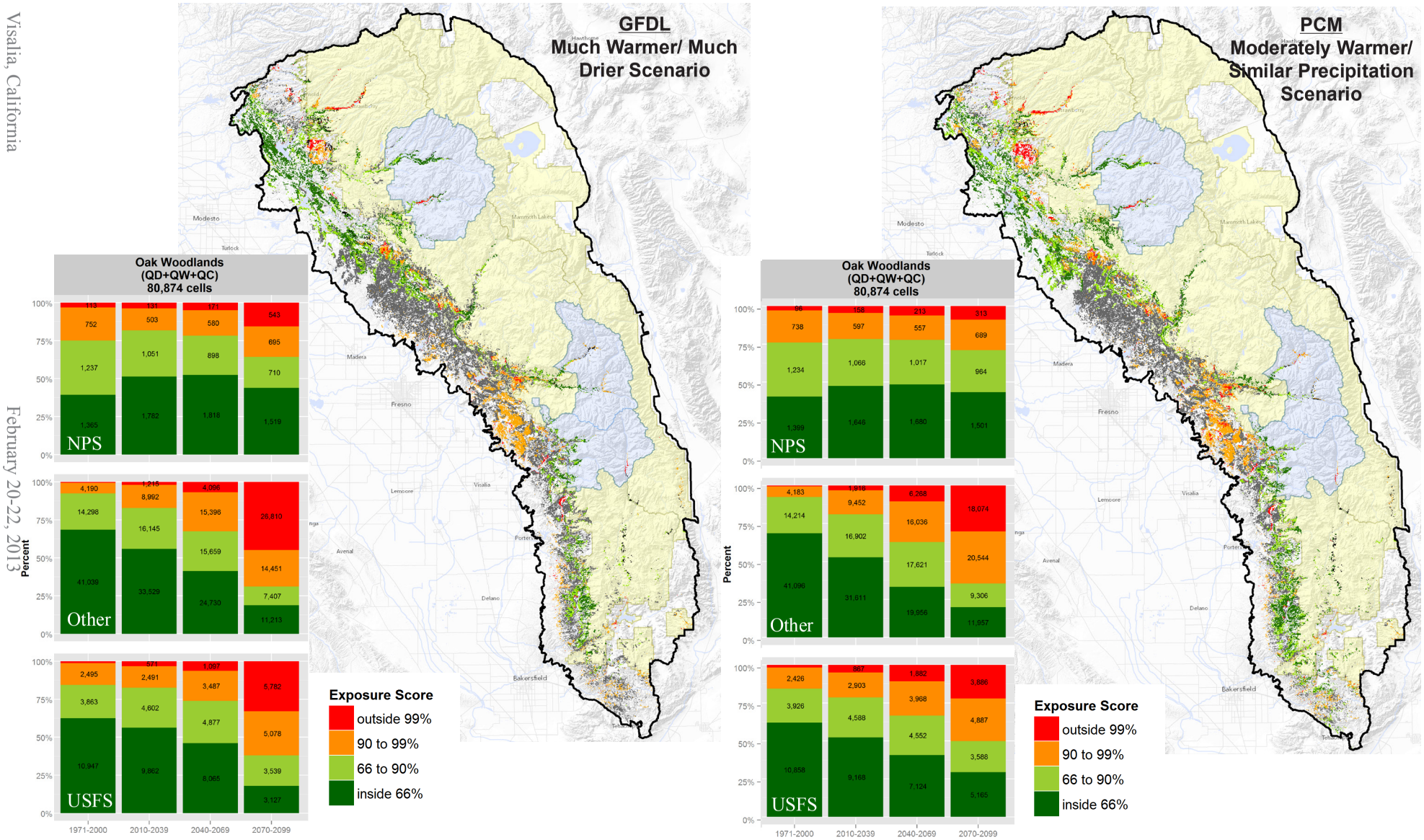

Figure 3: Two scenarios of future climate exposure for oak woodlands in the southern Sierra Nevada study area. Maps show grove area predicted to be at risk soonest (high exposure in 2010-2039) in red and orange; resilient longest (low exposure in 2070-2099) in dark and light green; and at risk later (i.e, high exposure by 2070-2099) in gray. Blue borders = NPS; yellow shading = USFS. Bar graphs show percent of study area falling within different climate exposure score categories over time (1971-2000; 2010-2039; 2040-2069; 2070-2099) for NPS, other, and USFS lands. Exposure score percentiles are based on projected future climate conditions compared to the baseline (1971-2000) climate envelope for oak woodlands, which include blue oak, interior live oak, and canyon live oak CalVeg types. These results use the IPCC A2 emissions scenario. Adapted from Schwartz et al. In Prep.

POSSIBLE FUTURE CHANGES

In the future, the biggest stressors or threats to oak woodlands include land use change, (urbanization) and overbrowsing (cattle and deer), though changing climate also has the potential to drive significant changes. Although predicting future climates is extremely complex, the three main IPCC emission scenarios agree that temperature in the southern Sierra Nevada will warm, with predictions between +2.6 to 3.9°C by 2100[29]. Less certain is the change in precipitation – of the 18 general circulation models that include California, about half predict decreases and half predict increases for the Sierra region[33]. Even with little changes in precipitation, the increased temperatures would increase drought stress (higher rates of evapotranspiration), and could cause changes in wildfire regimes, snowmelt patterns, and more (see Table 1). Longer dry seasons may compromise oak recruitment, as seedling survival is dependent on sufficient rainfall[13,14,28].

Lower elevation oaks, such as blue oak, are predicted to experience high climate stress at the lower edge of their range[32], which may lead to loss of oak habitat at these elevations, especially dryer south facing slopes. Expansion upslope beyond the current range is predicted if soils are suitable[32] and if they can successfully disperse upslope and establish new individuals. Another way of projecting potential change is shown in Figure 3, which shows oak woodlands areas predicted to be at "high risk soonest" and "most resilient longest" (potential climate refugia) under two future scenarios. Figure 4 shows modeled projections of where blue oak will be stressed, stable (i.e., climate refugia), or may undergo range expansion in lower portion of the S. Sierra. However, species distribution model results vary by species' traits[34] and model results can vary greatly depending on model used[35], so caution should be exercised when using model results.

Climate change also may affect oak woodlands by altering fire regimes. Different climate change scenarios produce divergent projections of future fire probability for the lower elevations of oak woodlands, but agree on generally higher fire probabilities for their upper elevations (Figure 2)[36]. Higher fire probability could be beneficial or detrimental for oak woodlands and research on the subject is mixed. Some study suggests that more fire will favor oaks[6] while increased fire frequency and severity may have no effect on new recruitment. The regions of higher fire probability coincide with areas that are predicted to be oak climate refugia or expansion zones, which illustrates the potential importance of interactions among direct and indirect climate change effects.

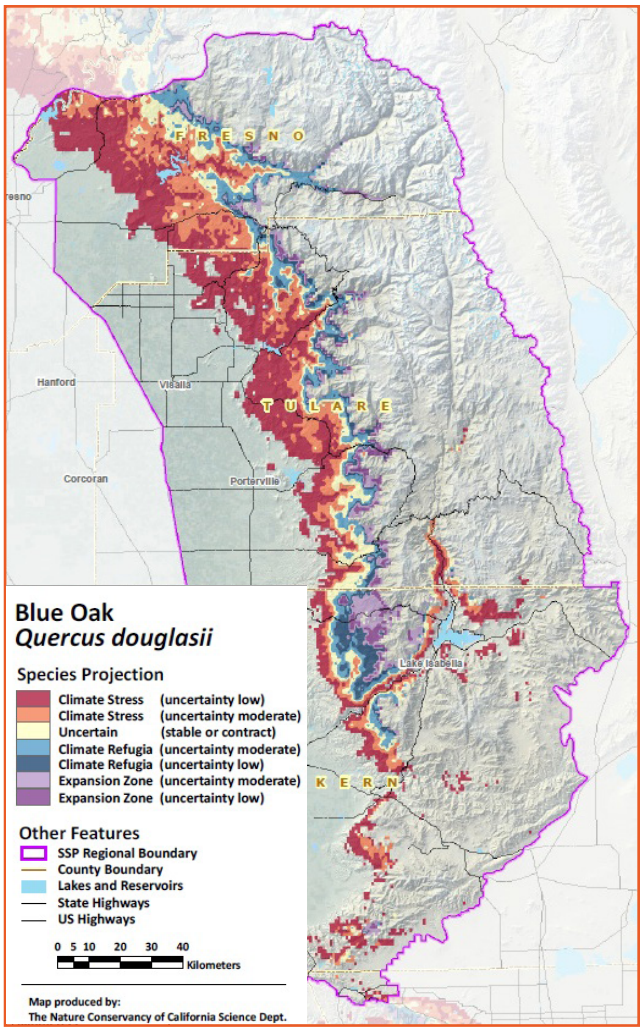

Figure 4: Species projection for 2045-2065 for blue oak in the most southern portion of the PACE. These results are based on 11 climate models with uncertainty determined by number of models that disagree. Figure adapted from Southern Sierra Partnership.

Authorship Note

This information brief was created by Bill Kuhn (NPS) and Katy Cummings (NPS), with review and contributions from Susan Antenen (Conservation Biology Institute), Koren Nydick (NPS), and Eric Winford (NPS). Additional thanks to Erika Willaims (NPS) for graphic design assistance.

POTENTIAL MANAGEMENT STRATEGIES (WORK IN PROGRESS)

- To manage for persistence (resist change and build resilience):
  - Suppress fires in critical regeneration areas to allow saplings to mature
  - Reduce the fire return interval departure by allowing more fires to burn
  - Construct deer fences around sapling oaks
  - Manage the ungulate (deer) populations where appropriate and possible
  - Control invasive forbs and grasses in oak understory
  - Limit/reduce stock grazing in all areas to enhance recruitment
  - Protect emerging seedlings from browsers

- To manage for change (facilitate transformation):
  - Assist migration of oaks upslope through acorn plantings
  - Protect oak woodlands along elevational gradients

- Delay deciding (monitor and research):
  - Map shifts in distribution of oak woodlands
  - Monitor changes in oak abundance/
  - Map where oak recruitment is occurring and look for correlations between other factors
  - Monitor shifts in native plant biodiversity to exotic plant biodiversity
  - Monitor introduction and spread of pathogens (sudden oak death; gold spotted oak borer)

References

1 Verner, J. 1980. Birds of California oak habitats - management implications. Pages 246-262 In: T. R. Plumb, editor. Proceedings of the Symposium on the Ecology, Management, and Utilization of California Oaks. USDA Forest Service, Pacific Southwest Research Station, San Diego, CA.

2 Barrett, R.H. 1980. Mammals of California oak habitats - management implications. Pages 275-291 in T. R. Plumb, editor. Proceedings of the Symposium on the Ecology, Management, and Utilization of California Oaks. USDA Forest Service, Pacific Southwest Research Station, San Diego, CA.

3 Block, W.M. and M.L. Morrison. 1998. Habitat relationships of amphibians and reptiles in California oak woodlands. Journal of Herpetology 32:51-60.

4 Bolsinger, C.L. 1980. California forests: trends, problems, and opportunities. Resources Bulletin PNW-89, USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, OR.

5 Bolsinger, C.L. 1988. The hardwoods of California's timberlands, woodlands, and savannas. Resource Bulletin PNW-RB-148, U.S. Dept. of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, OR.

6 Thorne, J.H., B.J. Morgan, and J.A. Kennedy. 2008. Vegetation change over sixty years in the Central Sierra Nevada, California, USA. Madrono 55:223-237.

7 Spero, J.G. 2002. Development and fire trends in oak woodlands of the northwestern Sierra Nevada foothills. Pages 287-301 in R. B. t. e. Standiford, editor. Proceedings of the Fifth Symposium on Oak Woodlands: Oaks in California's Challenging Landscape. U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Albany, CA.

8 Huntsinger, L., L. Buttolph, and P. Hopkinson. 1997. Ownership and management changes on California hardwood rangelands: 1985 to 1992. Journal of Range Management 50:423-430.

9 Huntsinger, L. and L.P. Fortmann. 1990. California's privately owned oak woodlands: Owners, use, and management. Journal of Range Management 43:147-152.

10 Greenwood, G. B., R.K. Marose, and J.M. Stenbeck. 1993. Extent and ownership of California's hardwood rangelands. California Dept of Forestry and Fire Protection, Strategic and Resources Planning Program, Sacramento.

11 Ewing, R.A., N. Tosta, R. Tuazon, L. Huntsinger, R. Marose, K. Nielson, R. Motroni, and S. Turan. 1988. Growing conflict over changing uses. Forest and Rangeland Resources Assessment Program (FRAP), California Dept. of Forestry and Fire Protection, Sacramento, CA.

12 Winford, 2012. Foothill Vegetation, 12-13.

13 Tyler, C., B. Kuhn, and F. Davis. 2006. Demography and recruitment limitations of three oak species in California. The Quarterly Re-

view of Biology 81:127-152.

14 Davis, F.W., C.M. Tyler, and B.E. Mahall. 2011. Consumer control of oak demography in a Mediterranean-climate savanna. Ecosphere 2:art108.

15 Kuhn, B.A. 2010. Road systems, land use, and related patterns of Valley oak (Quercus lobata Nee) populations, seedling recruitment, and herbivory. Dissertation. University of California, Santa Barbara.

16 Ripple, W.J. and R.L. Beschta. 2008. Trophic cascades involving cougar, mule deer, and black oaks in Yosemite National Park. Biological Conservation 141:1249-1256.

17 Borchert, M. 1990. From acorn to seedling: a perilous stage. Fremontia 18:3-37.

18 Kuhn, B. and B. Johnson. 2008. Status and trends of Black Oak (Quercus kelloggii) populations and recruitment in Yosemite Valley. Yosemite National Park, Yosemite, CA.

19 Standiford, R. B., N. McDougald, W. Frost, and R. Phillips. 1997. Factors influencing the probability of oak regeneration on southern Sierra Nevada woodlands in California. Madrono 44:170-183.

20 Rodriguez-Buritica, S., K. Suding. 2012. Foothill Vegetation. Appendix 8 in: National Park Service. 2012. Natural Resource Condition Assessment for Sequoia and Kings Canyon National Parks. Natural Resource Report NPS/SEKI/NRR-2012/XXX. Eds. J.A. Panek and C.A. Sydoriak. National Park Service, Fort Collins, CO. Internet address: www.nature.nps.gov/publications/NRPM.

21 Swiecki, T. J., E.A. Bernhardt, and C. Drake. 1997. Factors affecting blue oak sapling recruitment. Pages 157-161 in J. V. N.H. Pillsbury, and W.D. Tietje, editors. Symposium on oak woodlands: ecology, management, and urban-interface issues. USFS Pacific Northwest Research Station, San Luis Obispo, CA.

22 Swiecki, T.J., E.A. Bernhardt, and C. Drake. 1993. Factors affecting blue oak sapling recruitment and regeneration. Forest and Rangeland Resources Assessment Program Report, California Dept. of Forestry and Fire Protection, Sacramento, CA.

23 Swiecki, T.J., E.A. Bernhardt, and C. Drake. 1997. Stand-level status of blue oak sapling recruitment and regeneration. Pages 147-156 in J. V. N.H. Pillsbury, and W.D. Tietje, editors. Symposium on oak woodlands: ecology, management, and urban-interface issues. USFS Pacific Northwest Research Station, San Luis Obispo, CA.

24 Mensing, S.A. 1992. The impact of European settlement on blue oak (Quercus douglasii) regeneration and recruitment in the Tehachapi Mountains, California. Madrono 39:36-46.

25 Southern Sierra Partnership (SSP). 2010. Framework for Cooperative Conservation and Climate Adapatiation for the Southern Sierra Nevada and Tehachapi Mountains, California, USA. Appendix B, pages XXVIII-LXVIII.

26 Biswell, H.H. 1989. Prescribed burning in California wildlands vegetation management. University of California Press, Berkeley, CA.

27 McCarthy, H. 1993. Managing oaks and the acorn crop. Pages 213-228 In: T. C. Blackburn and K. Anderson, editors. Before the wilderness: environmental management by native Californians. Ballena Press, Menlo Park, CA.

28 Pavlik, B.M., P.C. Muick, S.G. Johnson, and M. Popper. 1991. Oaks of California. Cachuma Press, Inc, Los Olivos, CA.

29 Gonzalez, P., R.P. Neilson, J.M. Lenihan, and R.J. Drapek. 2010. Global patterns in the vulnerability of ecosystems to vegetation shifts due to climate change. Global Ecology and Biogeography 19: 755-768.

30 Null, S.E., J.H. Viers, and J.F. Mount. 2010. Hydrologic response and watershed sensitivity to climate warming in California's Sierra Nevada. PLoS One 5: e9932.

31 Young, C.A., M.I. Escobar-Arias, M. Fernandes, B. Joyce, M. Kiparsky, J.F. Mount, V.K. Mehta, D. Purkey, J.H. Viers, and D. Yates. 2009. Modeling the hydrology of climate change in California's Sierra Nevada for subwatershed scale adaptation. Journal of the American Water Resources Association 45: 1409-1423.

32 Cayan, D.R., E.P. Maurer, M.D. Dettinger, M. Tyree, and K. Hayhoe. 2008. Climate change scenarios for the California region. Climatic Change 87:21-42.

33 Gonzalez, P. 2012. Climate change trends and vulnerability to biome shifts in the southern Sierra Nevada DRAFT. National Park Service, Washington, D.C.

34 Dobrowski, S.Z., J.H. Thorne, J.A. Greenberg, H.D. Safford, A.R. Mynsberge, S.M. Crimmins, and A.K. Swanson. 2011. Modeling plant ranges over 75 years of climate change in California, USA: temporal transferability and species traits. Ecological Monographs 81:241-257.

35 Kueppers, L.M., M.A. Snyder, L.C. Sloan, E.S. Zavaleta, and B. Fulfrost. 2005. Modeled regional climate change and California endemic oak ranges. Proceedings of the National Academy of Sciences of the United States of America 102:16281-16286.

36 Moritz, M. Mortiz Lab, University of California at Berkeley. Unpublished data.